## COMPRESSION FEED DEVICE FOR HIGH HUMIDITY FUEL GAS

## BACKGROUND OF THE INVENTION

- 1. Field of the Invention
- [0001] The present invention relates to a gas compression feed device used when operating a small-sized microturbine power generating facility using as a fuel so-called "high humidity fuel gas" which can burn since it is mainly comprised of methane gas, but which includes a high concentration of moisture, such as the biogas generated in sewage treatment plants.
  - 2. Description of the Related Art
- In general, when using a high humidity fuel gas [0002] as the fuel of a microturbine, it is necessary to compress the high humidity fuel gas by a compressor to raise it to a pressure sufficient for use as the fuel of a turbine such as 400 kPa to 600 kPa. In the compression feed device of high humidity fuel gas used for this, normally, as shown in FIG. 2, the introduced high humidity fuel gas G1 is compressed by the gas compressor 3 and the high humidity fuel gas discharged from the compressor 3 is sent to a receiver tank 51 to make it discharge heat and thereby enable the moisture condensed and liquefied inside the high humidity fuel gas to be separated and removed by gravity. The fuel gas G5 from which moisture has generally been removed is then sent through discharge piping 10 and a discharge port 11 to the not shown microturbine. Note that the compressor 3 is provided with a cooling conduit 4 and is cooled by a heat medium such as circulating cooling water absorbing the heat of compression, but this heat is not utilized, but discharged into the atmosphere from the walls of a heat medium tank 21, the not shown radiator, etc.
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since it is necessary to provide two adsorption tanks 51a, 51b and two switches 50a, 50b and to provide means for controlling the operation of the switches 50a, 50b, there are the problems that the capital cost and the running costs become higher and that the turbine used for frequently regenerating the adsorption tanks consumes a large amount of power. Further, in the prior art shown in FIG. 4, there are the problem that the refrigerant compressor etc. provided in the refrigeration cycle of the refrigeration machine consumes large drive power (electric power) and the problem that the facility becomes complicated and high in price. Therefore, neither method can necessarily be said to be the best.

## SUMMARY OF THE INVENTION

[0007] An object of the present invention is to provide a compression feed device for high humidity fuel gas of a novel configuration which deals with the above problems in the prior art and solves all of these problems, is simple and inexpensive in system configuration yet can sufficiently separate and remove moisture contained in high humidity fuel gas and thereby enables a microturbine to be safely operated and also consumes far less drive power (electric power) for operation compared with the prior art.

[0008] To attain the above object, there is provided a compression feed device for high humidity fuel gas which compresses high humidity fuel gas, removes moisture, and feeds the gas to a microturbine power generator by being provided with a compressor for receiving and compressing high humidity fuel gas, an air-cooling type fin-tube radiator for cooling the compressed high humidity fuel gas to condense and liquefy the moisture, a moisture-removing means for separating and removing the condensed and liquefied moisture from the cooled high humidity fuel gas, and a heat exchanger for heating the fuel gas from then moisture-removing means, then passing it to a pipe leading to the microturbine power generator and which

uses the heat of compression generated in the compressor so as to heat the fuel gas in the heat exchanger by being provided with a heat medium circulation system comprised of a cooling conduit provided at the compressor, a heating conduit provided at the heat exchanger, and a heat medium circulation pump for circulating the heat medium through the cooling conduit of the compressor and the heating conduit of the heat exchanger.

[0009] In the compression feed device for high humidity fuel gas of the present invention, the compressor compresses the high humidity fuel gas, while an air-cooling type fin-tube radiator cools the compressed high humidity fuel gas to cause the moisture to condense. The condensed moisture is separated and removed by the later moisture-removing means. As the moisture-removing means, it is possible to use a mechanical gas/liquid separator, an adsorption type moisture-removing tank containing an adsorbent, etc. Since the majority of the moisture contained is condensed and liquefied by radiation of heat of the high humidity fuel gas, it is efficiently separated and removed by the moisture-removing means.

[0010] After the majority of the moisture is removed, the combustion gas is further sent to the heat exchanger and is heated by the heat medium circulation system utilizing the waste heat of the compressor, that is, the heat of compression. In this way, the fuel gas supplied to the microturbine power generator has the majority of the moisture contained in it removed, then is raised in temperature by the heat exchanger, so even if the temperature falls somewhat while the gas flows through the piping, the residual moisture will not condense and liquefy or freeze, so will not obstruct the operation of the turbine.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0011] These and other objects and features of the present invention will become clearer from the following

description of a preferred embodiment given with reference to the attached drawings, wherein:

- FIG. 1 is a system diagram illustrating an embodiment of a gas compression feed device according to the present invention;
- FIG. 2 is a system diagram illustrating a conventional gas compression feed device using a receiver tank;
- FIG. 3 is a system diagram illustrating a conventional gas compression feed device using an adsorption tank; and
- FIG. 4 is a system diagram illustrating a conventional gas compression feed device using a refrigeration machine.

[0012] A compression feed device of high humidity fuel gas shown in FIG. 1 will be explained as the best mode of working the present invention. A suction port 1 of the device is connected to a suction port of a compressor 3 by piping 2. As the compressor 3, it is possible to use a compressor of a reciprocating action type or other various types. The compressor 3 is provided with a cooling conduit 4 and can cool the compressor 3 by passing through it a liquid or gas state cooling medium. The discharge port of the compressor 3 is connected to an air-cooling type fin-tube radiator by piping 5. The radiator 6 has attached to it a cooling fan 6a driven by a motor 6b.

[0013] The outlet of the air-cooling type fin-tube radiator 6 is connected to the inlet of a gas/liquid separator 8 by piping. As the gas/liquid separator 8, it is possible to use one using centrifugal force such as a cyclone or a gas/liquid separator of various other types. The gas/liquid separator has a drain tank 8a and a drain cock 8b attached to it. The downstream side of the gas/liquid separator 8 has an adsorption type moisture-removing tank 7 connected to it. Inside it is contained

an adsorbent for adsorbing moisture. Note that while not shown, the adsorption type moisture-removing tank 7 is provided with a ventilating means or heating means for regenerating the adsorbent. Further, a drain cock 7a for exhausting the water separated at the time of regenerating is attached. In the present invention, the adsorption type moisture-removing tank 7 and the gas/liquid separator 8 are together called the "moisture-removing means". Provision of both the adsorption type moisture-removing tank 7 and the gas/liquid separator 8 is not a requirement.

[0014] The downstream side of the adsorption type moisture-removing tank 7 has a heat exchanger 9 connected to it. The heat exchanger 9 is provided with a heating conduit 9a and a heated conduit 9b. The piping extending from the adsorption type moisture-removing tank 7 is connected to the heated conduit 9b. Note that the type of the heat exchanger 9 may be any type, but for example it is possible to make the heating conduit 9a a spiral type pipe and make the entire inside space of the housing of the heat exchanger 9 containing the heating conduit 9a the heated conduit 9b.

[0015] The downstream side of the heat exchanger 9 is connected to a discharge port 11 of the device as a whole. The discharge port 11 is connected by piping 10 to an external microturbine power generator 12. In the compression feed device for high humidity fuel gas of the embodiment illustrated in the present invention, the conduits for the high humidity fuel gas and the fuel gas from which the moisture has been removed are configured as explained above.

[0016] The compression feed device of the illustrated embodiment is also provided with a heat medium circulation system as illustrated at the bottom of FIG. 1 in addition to the above conduits. This heat medium circulation system is configured by a heat medium tank 21, a heat medium circulation pump 22, a filter 23, the

cooling conduit 4 of the compressor 3, and the heating conduit 9a of the heat exchanger 9. The piping 24 and 25 are connected with each other and form a closed circuit so the heat medium 26 stored in the heat medium tank 21 is biased by the heat medium circulation pump 22 and forms a flow circulating in a predetermined direction shown by the arrow.

Since the compression feed device for high [0017] humidity fuel gas of the illustrated embodiment is configured as explained above, the suction high humidity fuel gas G1 introduced from the suction port 1 passes through the suction pipe 2, is sucked into the compressor 3 as the suction gas, is compressed by the compressor 3, and is raised in pressure to a predetermined pressure as the discharge compressed gas G2. This gas is heated and becomes high in temperature by being compressed, so is cooled by a simple configuration air-cooling type fintube radiator 6. Here, since the gas is cooled by the radiator 6 after being raised in pressure by the compressor 3, the moisture contained in the gas is condensed and liquefied and is separated from the fuel gas inside the gas/liquid separator 8.

The condensed water separated from the fuel gas [0018] by the gas/liquid separator 8 is stored in the attached drain tank 8a, so can be discharged by opening the drain cock 8b periodically. However, the radiator 6 is an aircooling type, so cannot completely condense and liquefy the moisture contained in the high humidity fuel gas. Therefore, if the fuel gas leaving the gas/liquid separator 8 is gradually cooled inside the piping 10 etc. leading to the downstream side microturbine power generator 12, the residual moisture might liquefy. Therefore, in the illustrated embodiment, the gas G3 containing the residual moisture leaving the radiator 6 is led to the adsorption type moisture-removing tank 7 where the slight residual moisture of the gas is adsorbed and removed by the adsorbent contained within. The gas G4

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Deliquescence type main type main comprised of potassium chloride,
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                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   6b: 35W, 5 m<sup>3/min</sup>
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25 kg

Heat exchanger 9: Heat transfer area 0.2  $\mathrm{m}^2$ , shell and tube type

[0024] Using the fabricated device, the suction pressure of the high humidity fuel gas G1 at the suction port 1 of the compressor 3 and the humidity at the temperature state were measured to verify the effects. The results obtained were as shown in Table 1. Note that in Table 1, the figures in parentheses were calculated by the later given calculation formula, but the other figures are actually measured values.

Measurement point	Absolute pressure (kPa)	Temperature (°C)	Moisture	Relative humidity (%)
Suction port (G1)	101.3	37	0.0349	85
G3	501	42	(0.0103)	_
G4	501	45	(0.0060)	(58)
Discharge	501	50	(0.0060)	35 (38)

Table 1

[0025] When the total pressure (kPa) is P and the steam partial pressure (kPa) is Pw, the maximum amount of moisture Xs (kg/kg') able to be contained in 1 kg of air is given by the following formula. The amount of moisture is the amount of moisture (weight of water indicated by "kg") per 1 kg' of air (weight of air indicated by "kg"). Note that Pw is found from a steam table.

$$Xs = 0.622 \times Pw/(P-Pw) \quad (kg/kg') \tag{1}$$

[0026] If calculating the amount of moisture at different parts by this formula (1), since the temperature is  $37^{\circ}\text{C}$  at Gl, Pw = 6.276, therefore,

$$xs = 0.622 \times 6.276/(101.3-6.276)$$

= 0.0410 (kg/kg')

The relative humidity is 85% in terms of actual measured value, so the actual amount of moisture becomes:

 $0.0410 \times 0.85 = 0.0349$ 

[0027] For G3, since the moisture is in a saturated

state, the pressure is 501 kPa, and the temperature is  $42^{\circ}$ C, Pw = 8.20, therefore

 $Xs = 0.622 \times 8.20/(501-8.20) = 0.0103$ 

[0028] For G4, the pressure does not change and the temperature is  $45^{\circ}$ C (Pw = 9.584). The moisture-removing tank 7 generally can reduce the humidity to a value of the same extent as the saturated state of a temperature about  $10^{\circ}$ C lower than the inlet temperature, so for an inlet temperature of  $42^{\circ}$ C, in the saturated state at  $32^{\circ}$ C, Pw = 4.755, therefore

 $xs = 0.622 \times 4.755/(501-4.755) = 0.0060$ and the relative humidity becomes 0.0060/0.0103 = 0.58, that is, 58%.

[0029] At G5, since the pressure is the same and the temperature is  $50^{\circ}$ C, Pw = 12.337, therefore

 $xs = 0.622 \times 12.337/(501-12.337)$ 

= 0.0157

of moisture can be contained, but in actuality the amount of moisture contained at G5 is 0.0060 kg/kg'. Since the relative humidity is the ratio of the amounts of moisture at G4 and G5, it becomes 38%.

[0030] When the temperature drops and reaches the saturation temperature, the moisture condenses and starts to liquefy, but the saturation temperature is 32°C. That is, the gas is discharged at 50°C and the moisture will not liquefy so long as the temperature does not drop by more than 12°C inside the piping 10 leading to the microturbine 12.

[0031] In this way, it was verified that the compression feed device for high humidity fuel gas of the illustrated embodiment has an actual power consumption of only the 35W required for driving the cooling fan 6a of the air-cooling type fin-tube radiator 6a and can feed sufficiently dried fuel gas to the microturbine power generator 12.

[0032] Summarizing the effects of the invention, the

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present invention gas characterized first by use radiator

high humidity fuel gas air-conting type fin-tube radiator
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illustration, it should be apparent that numerous modifications could be made thereto by those skilled in the art without departing from the basic concept and scope of the invention.